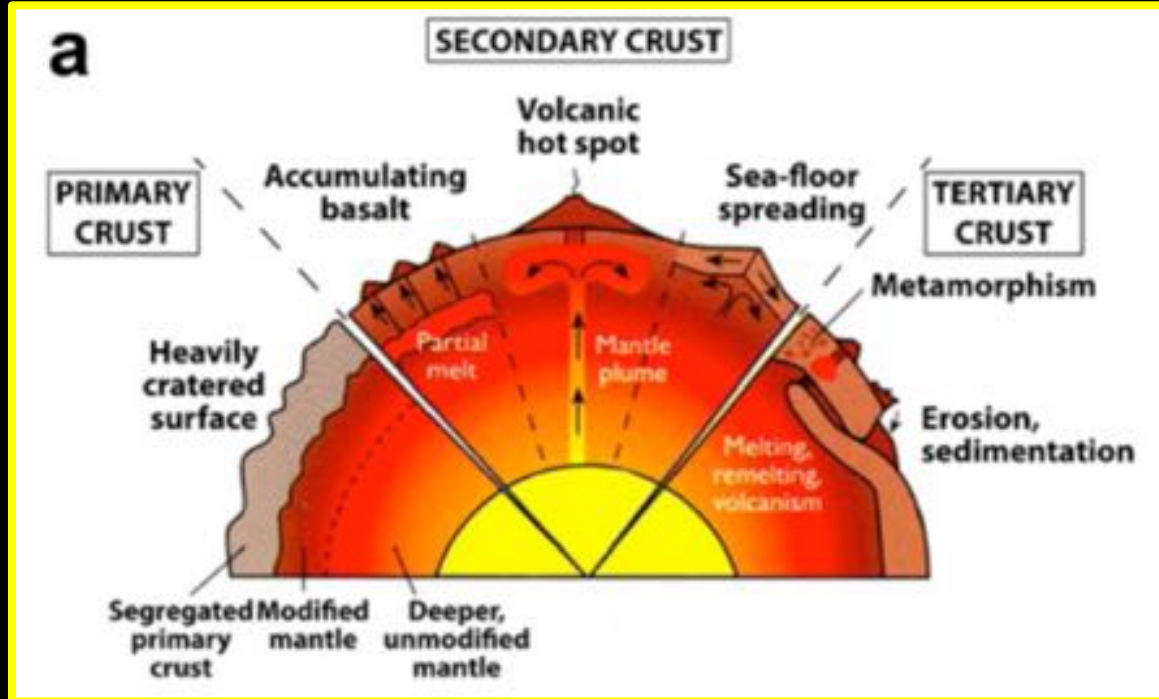
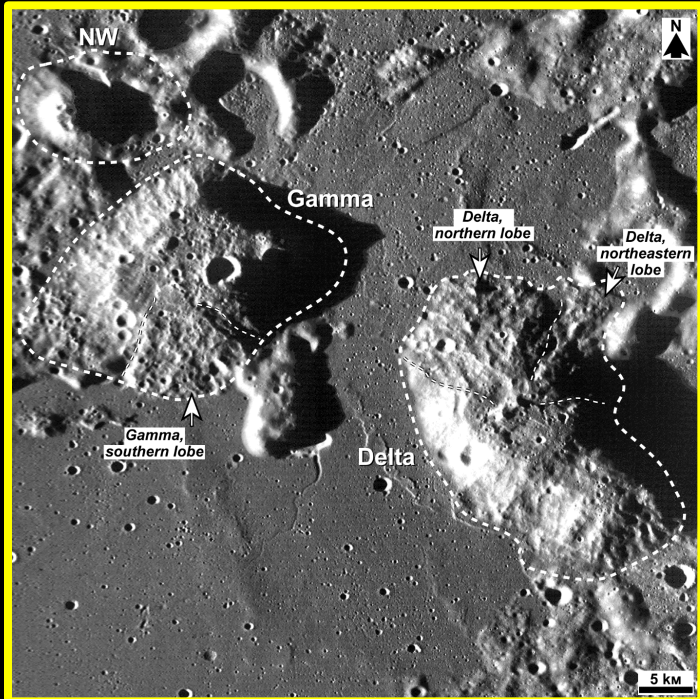


LUNAR NON-MARE VOLCANISM: THE ROLE OF COMMERCIAL MISSIONS IN THE EXPLORATION OF THE GRUITHUISEN DOMES



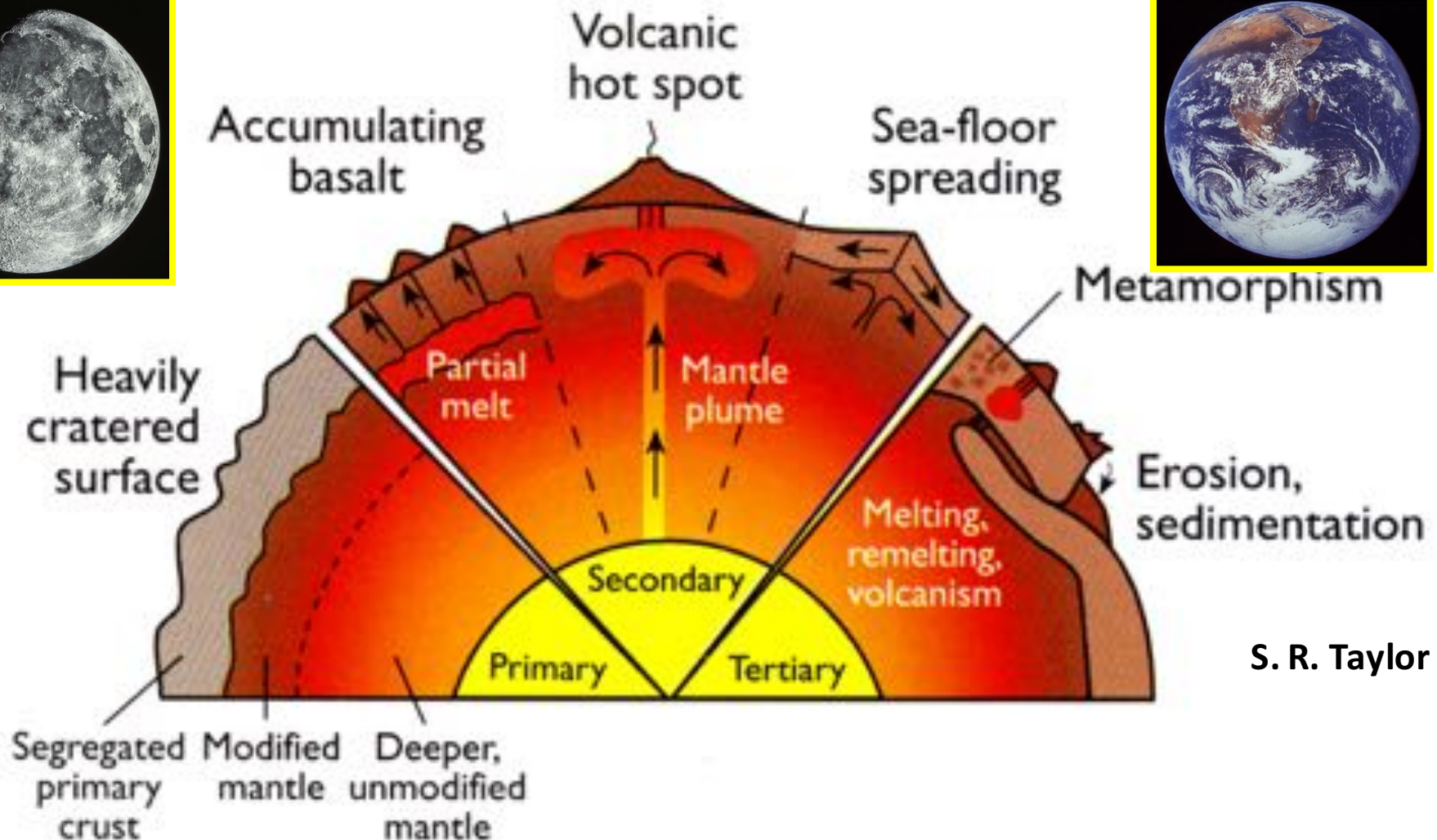
M. A. Ivanov^{1,2}, J. W. Head², and Lionel Wilson³.

¹Vernadsky Inst., RAS, Moscow, Russia,

²Dept. Earth, Env. and Planetary Sci, Brown Univ., Providence RI, 02912 USA,

³Lancaster Env. Centre, Lancaster Univ., Lancaster LA1 4YQ, UK.

Formation and Evolution of Planetary Crusts



S. R. Taylor

The Moon is a Laboratory for the Study of Primary and Secondary Crusts in Early Planetary History.

Lunar Rock Types

Maria



Basalt



Basalt



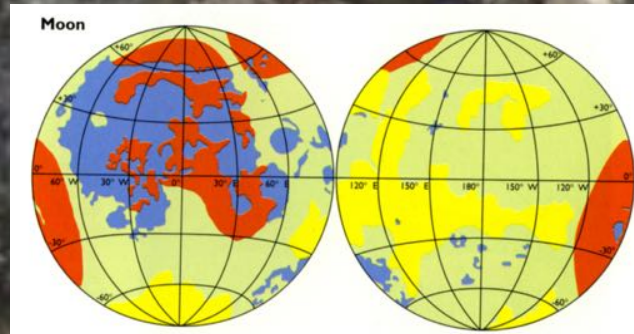
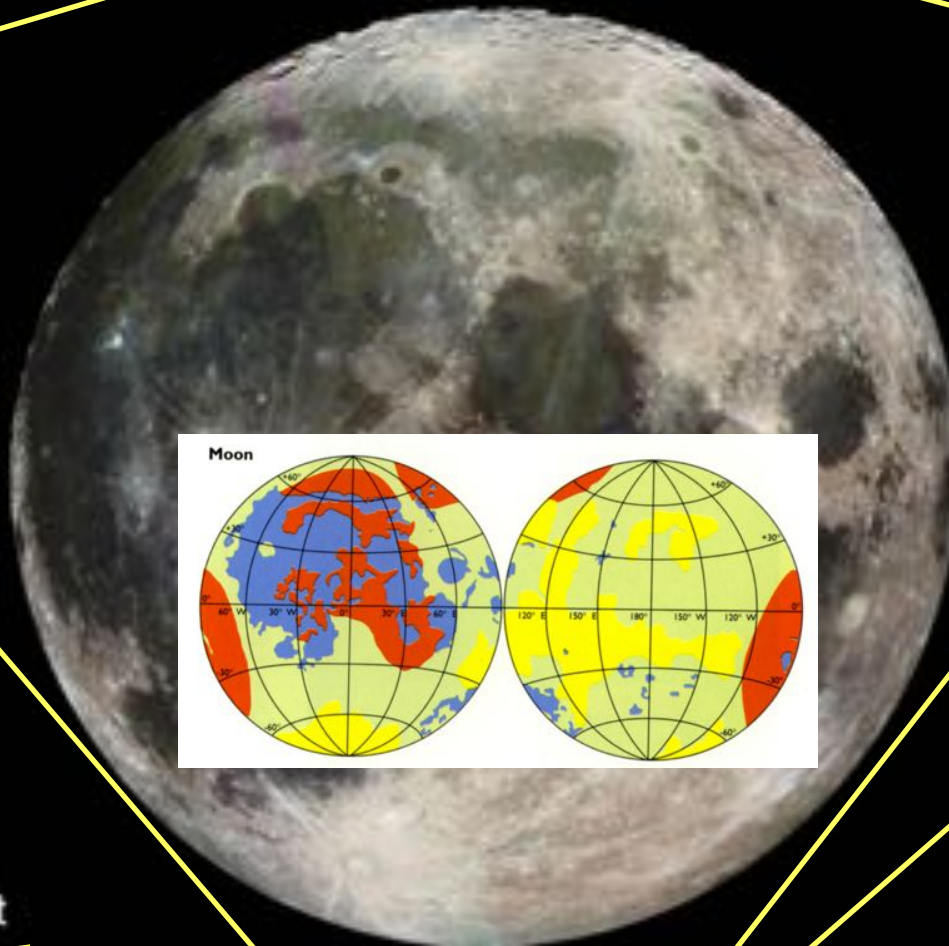
Anorthosite



Norite



Troctolite



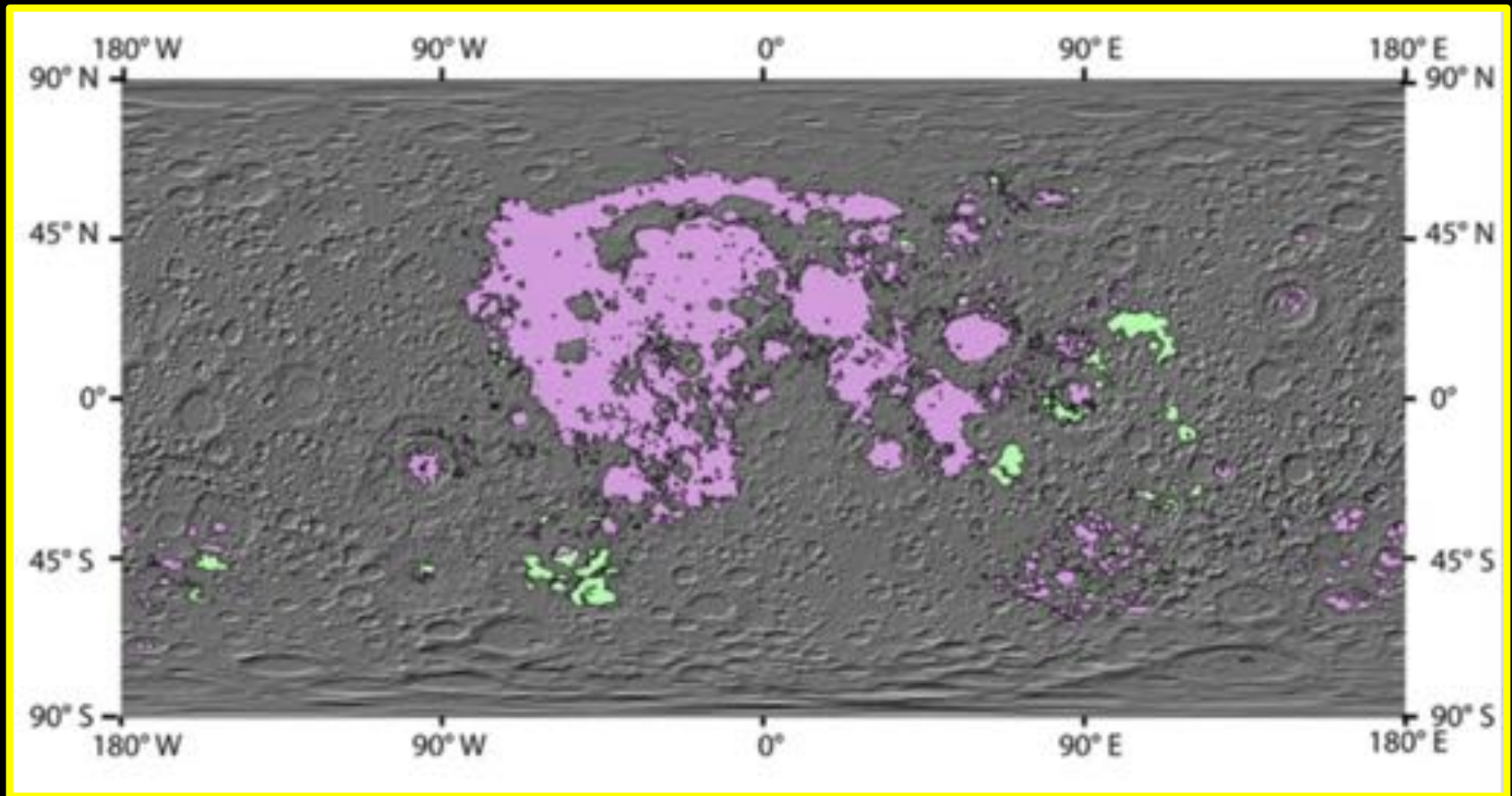
Breccia



Impact melt

Highlands

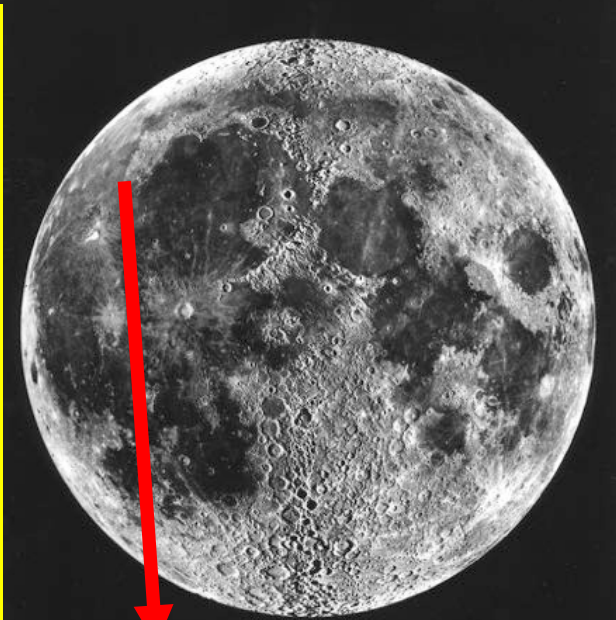
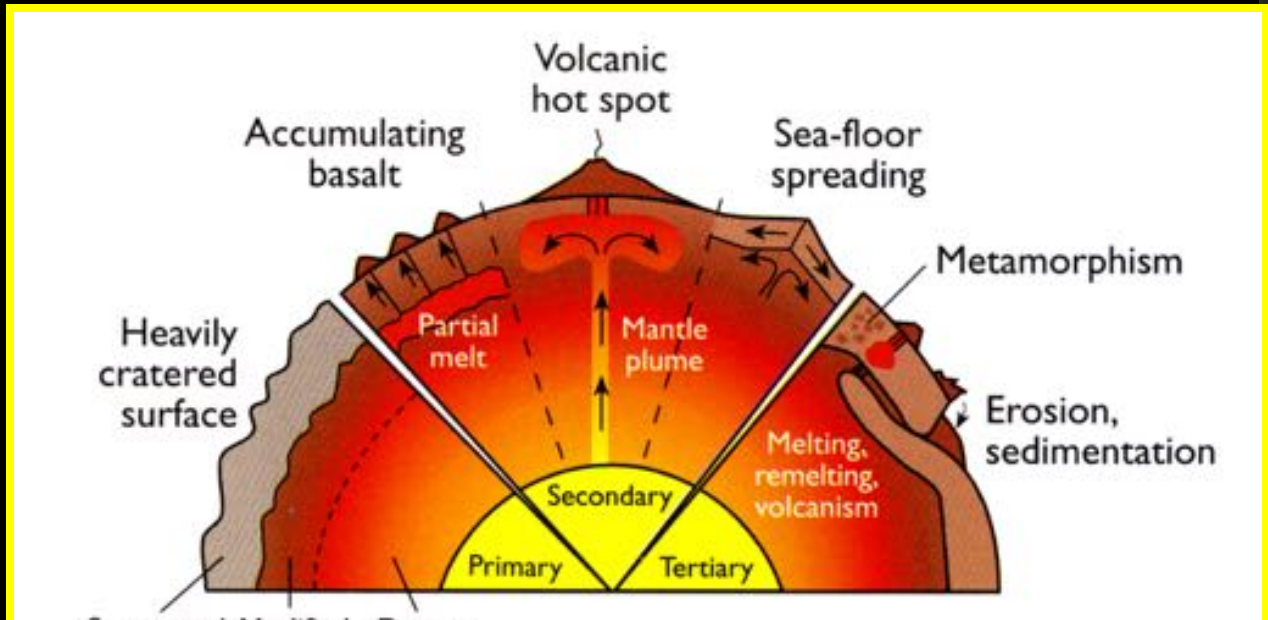
Secondary Crust: Lunar Maria and Cryptomaria



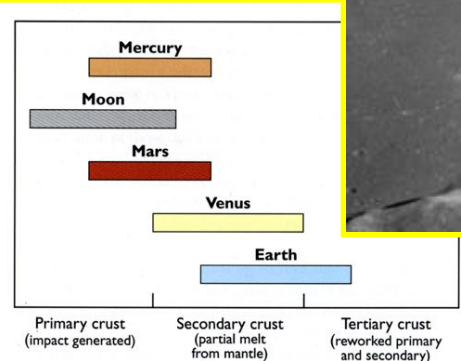
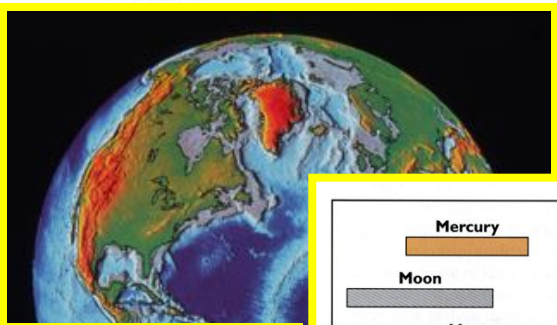
(Head and Wilson, 2017) (Whitten and Head, 2015a,b)

-Does the Moon have **Tertiary Crust** (reworked primary/secondary)?

Crustal Formation and Evolution: Primary, Secondary, Tertiary

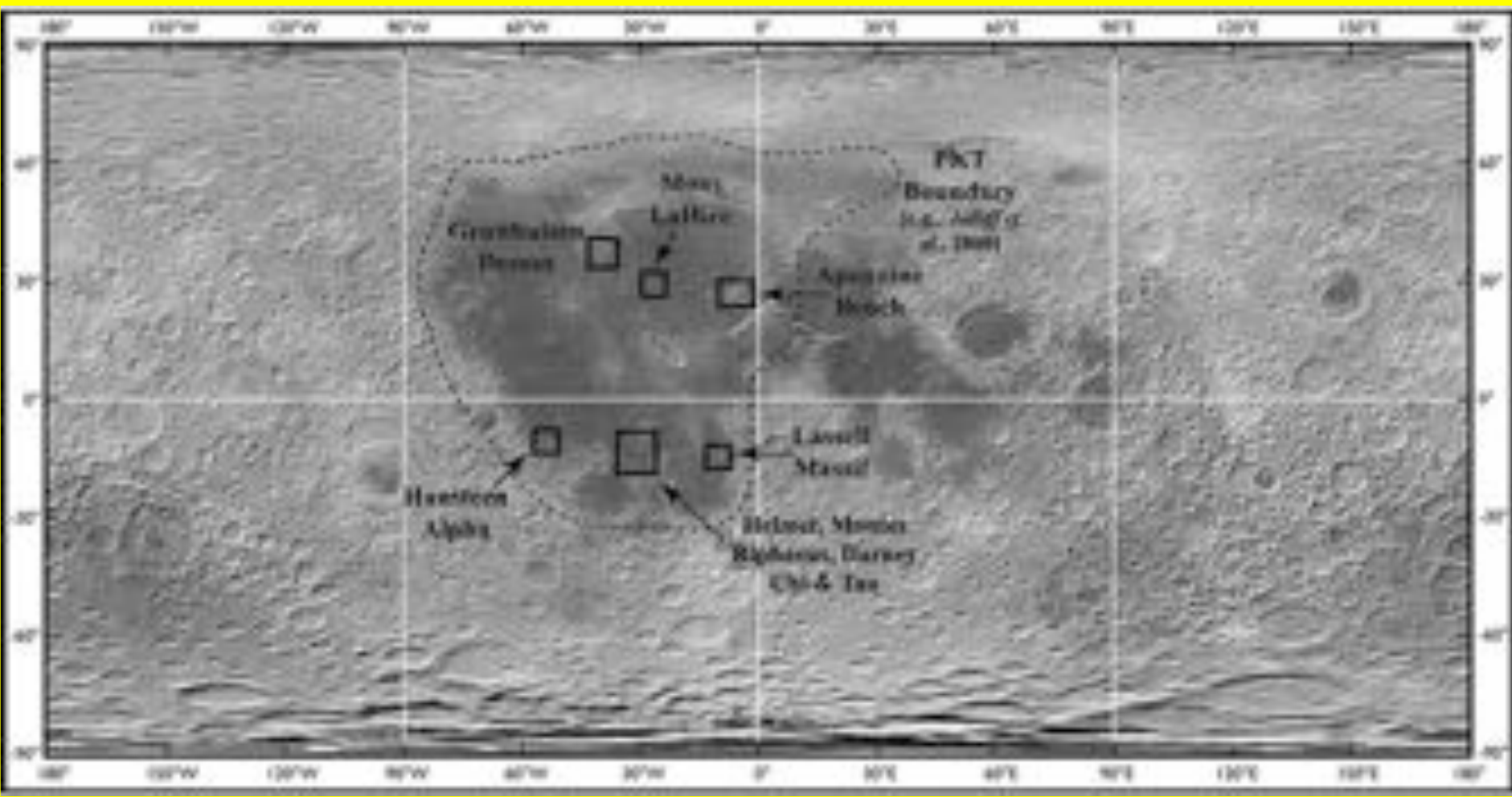


S. R. Taylor



Gruithuisen Domes - Felsic

Global Distribution of Red Spots



(Hagerty, 2014)

45°N, 312°E

Mairan

Gruithuisen

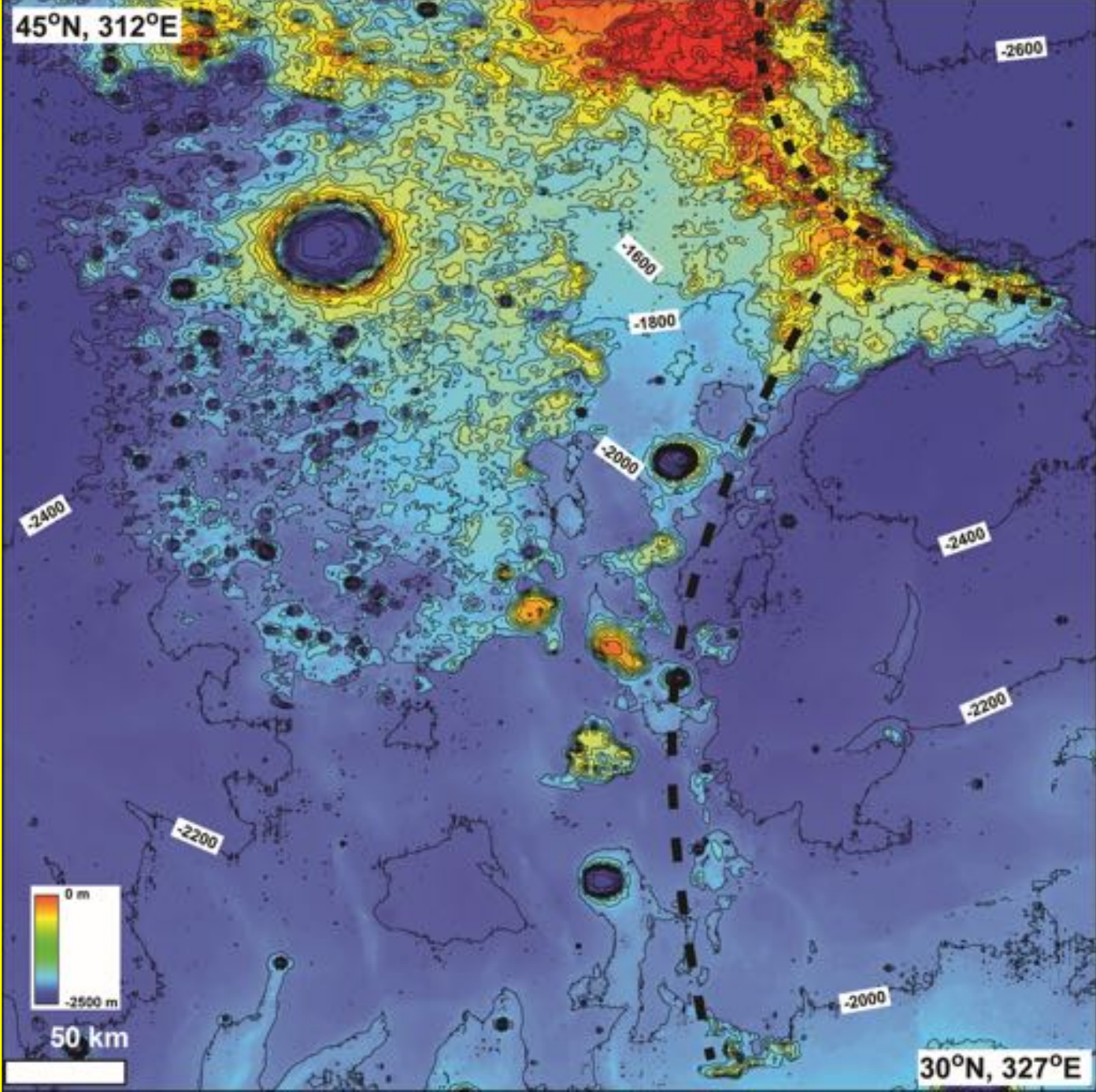
Delisle

30°N, 327°E

-  Ejecta, younger craters
 -  Mare materials
 -  Highland plains
 -  Gruithuisen domes
 -  Iridum melt pools
 -  Distal Iridum ejecta
 -  Proximal Iridum ejecta
 -  High-standing massifs
 -  rilles
 -  wrinkle ridges
- Highlands

50 km

(Ivanov et al., 2016)



(Ivanov et al., 2016)

45°N, 312°E

Mairan

melt pool-1

melt pool-2

Sinus



plains-W

NW

Gamma

Delta

mare-2

MARE
IMBRIUM

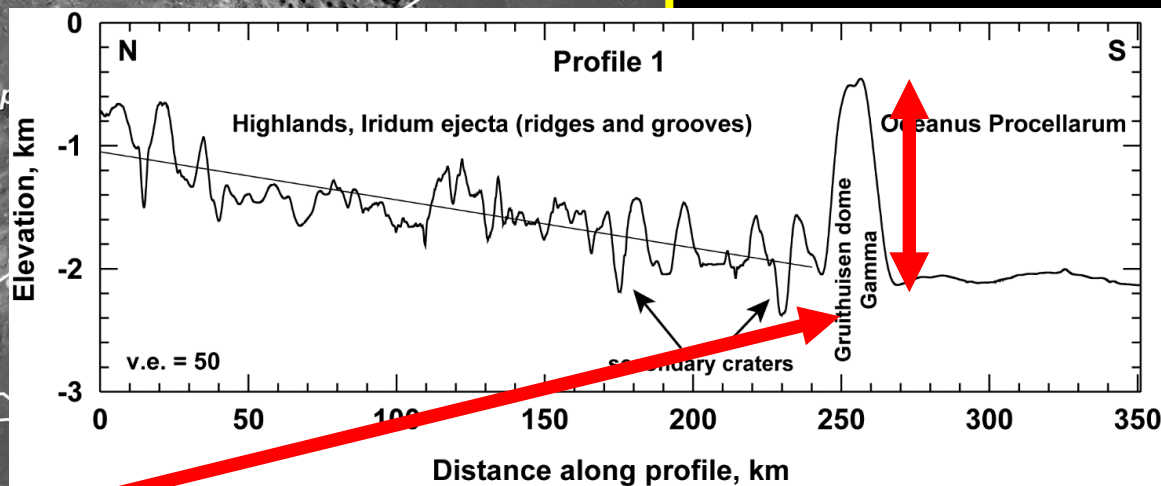
OCEAUNS
PROCELLARUM

Gruithuisen

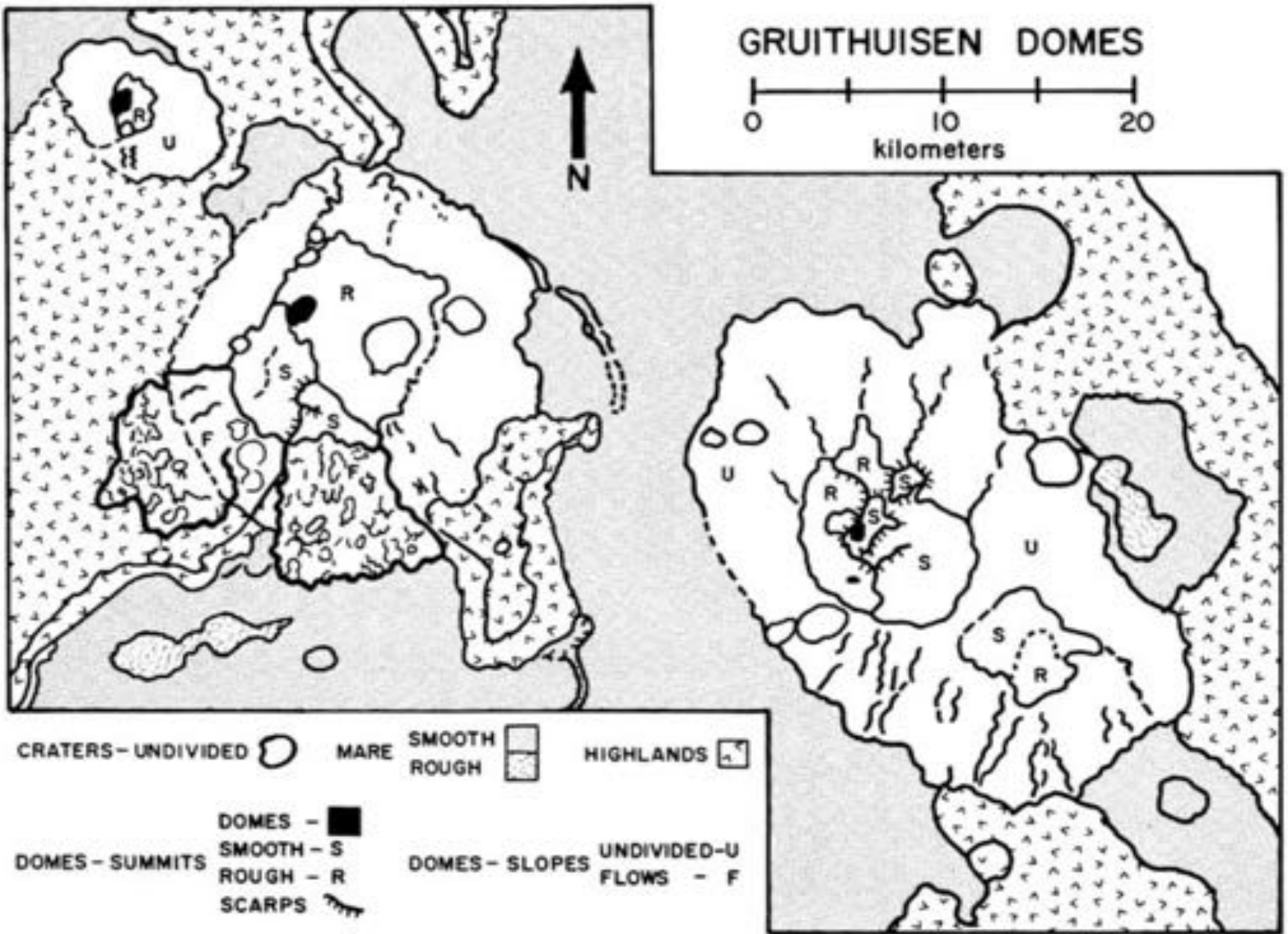
Delisle

50 km

30°N, 327°E

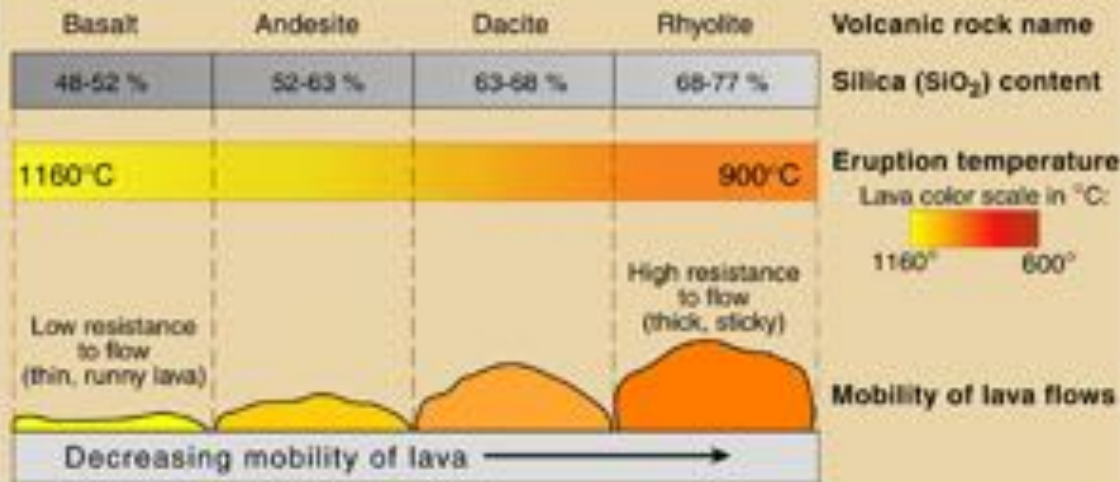


(Ivanov et al., 2016)



(Head and McCord, 1978)

CLASSIFICATION & FLOW CHARACTERISTICS OF VOLCANIC ROCKS



COMPONENTS OF IGNEOUS ROCKS



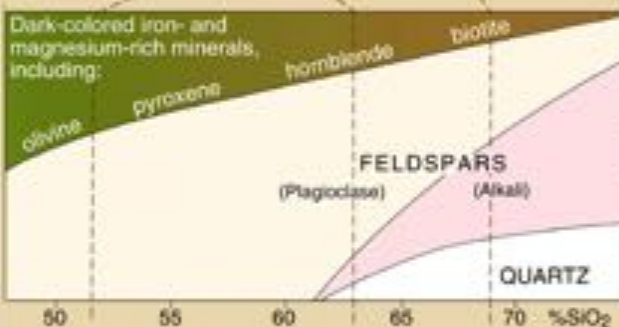
Lava flows typically produce rocks with 0-50% crystals (minerals) suspended in a fine-grained groundmass of glass and/or microscopic minerals.

Volcanic rock name



Coarse-grained rock; entirely crystalline with interlocking minerals in the proportions below. (Colors roughly correlate to graph below.)

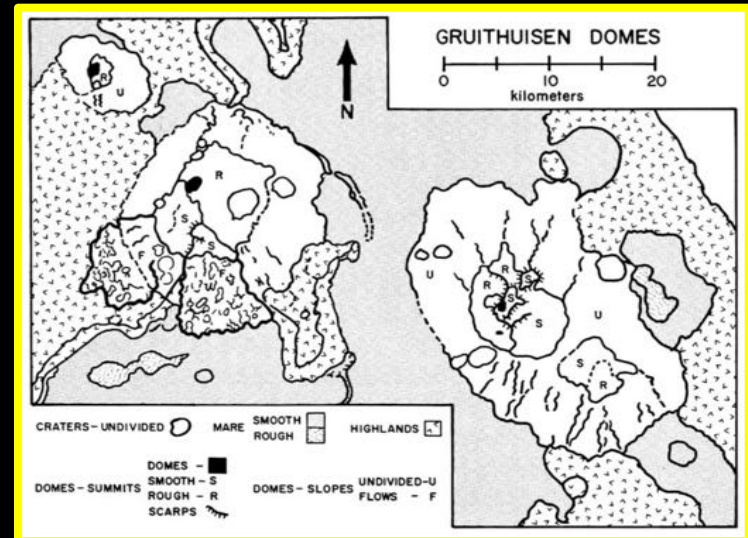
Plutonic rock name



Volume percent of minerals present in igneous rocks.

This generalized guide shows proportions of common minerals likely to be present in an igneous rock. (See text below on how to calculate.)

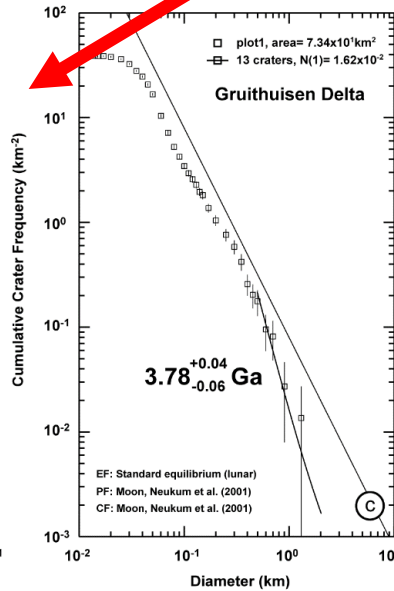
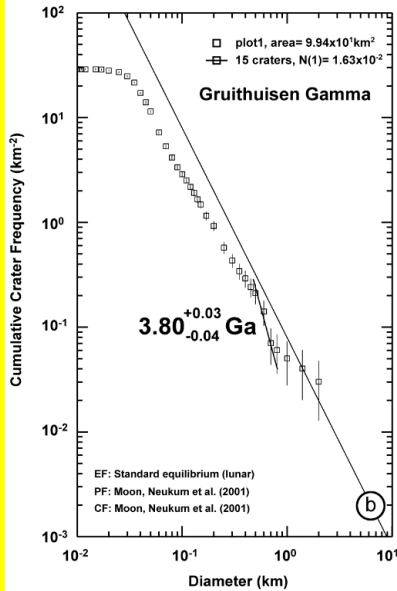
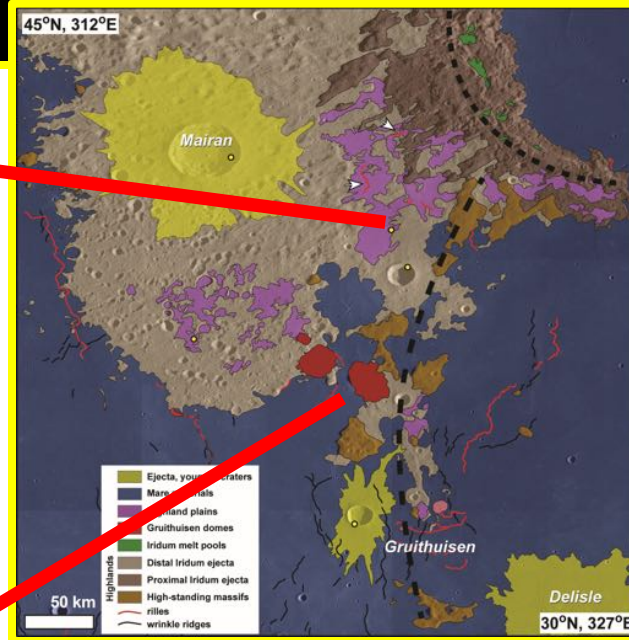
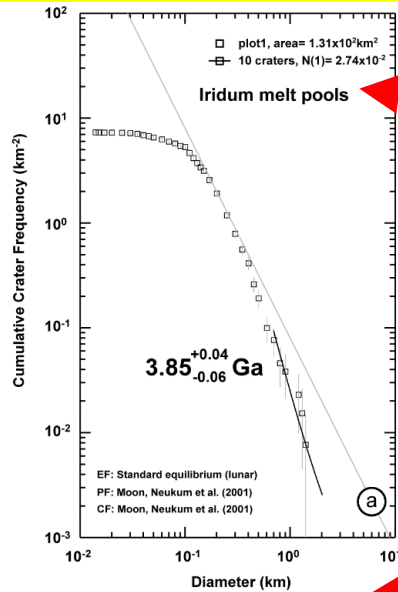
Plutonic rocks are entirely crystalline and have a larger variety of unusual minerals than volcanic rocks.



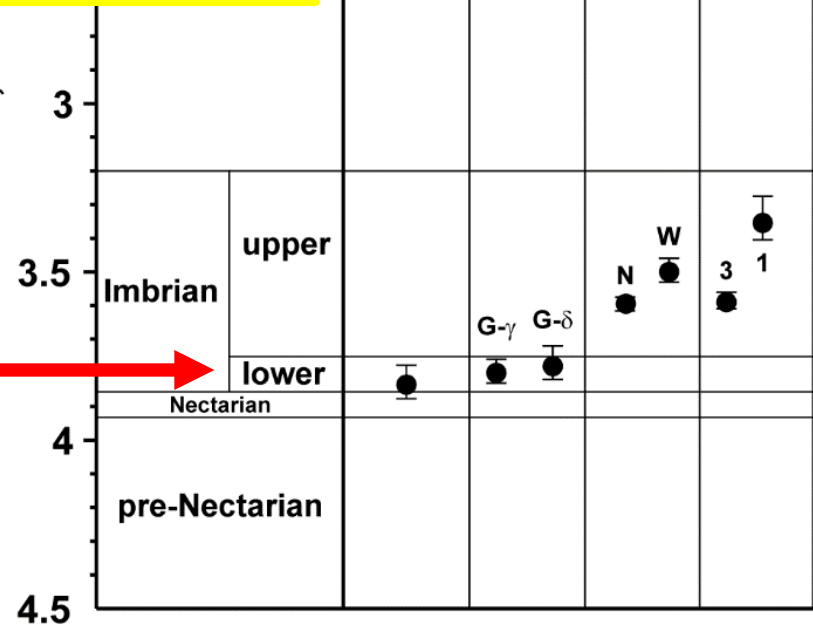
Yield strength 10^5 Pa, plastic viscosity 10^9 Pa s, effusion rates ~ 50 m³/s, emplacement decades.
(Wilson and Head, 2003)

Ages of the Gruithuisen Domes

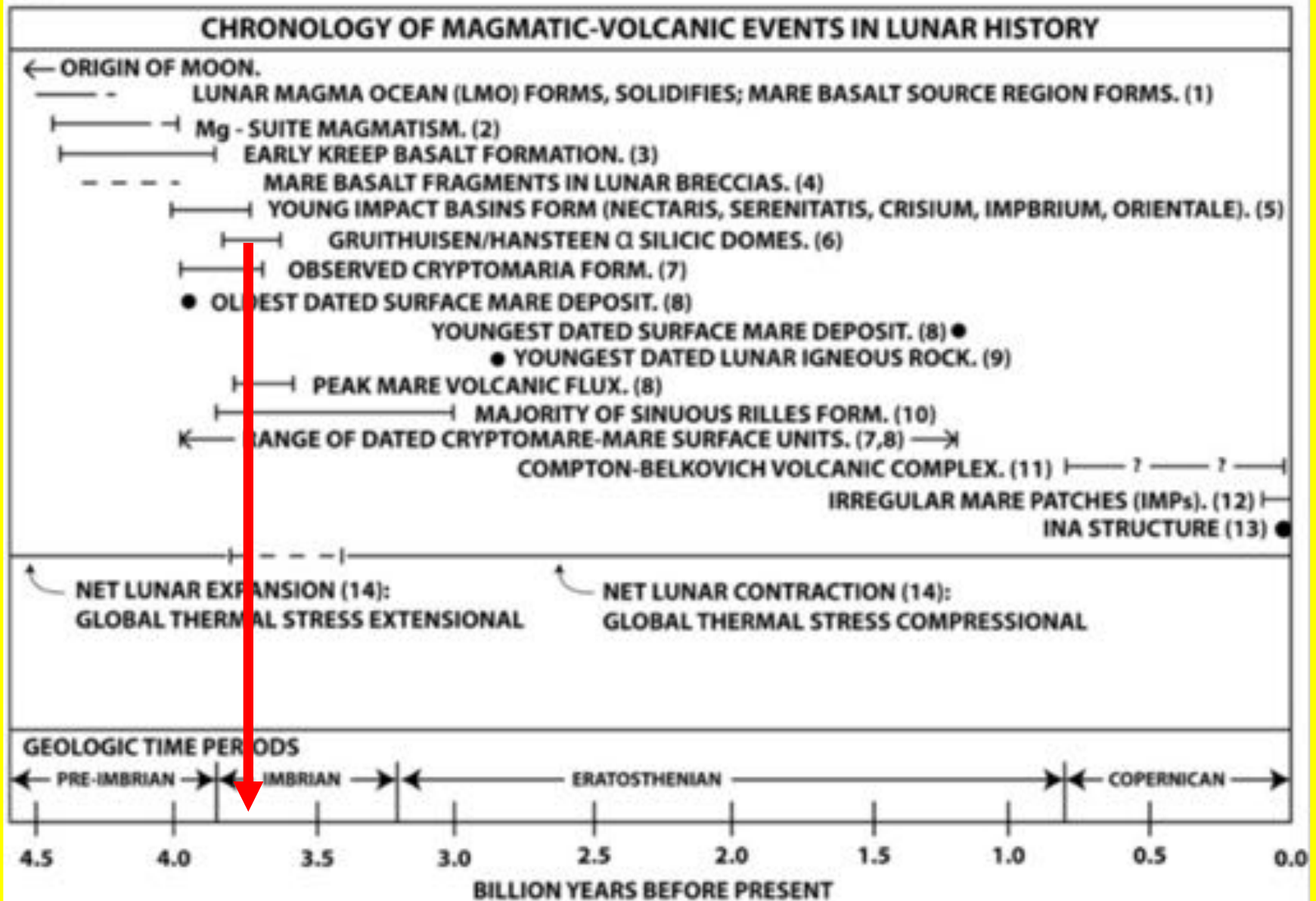
(Ivanov et al., 2016)



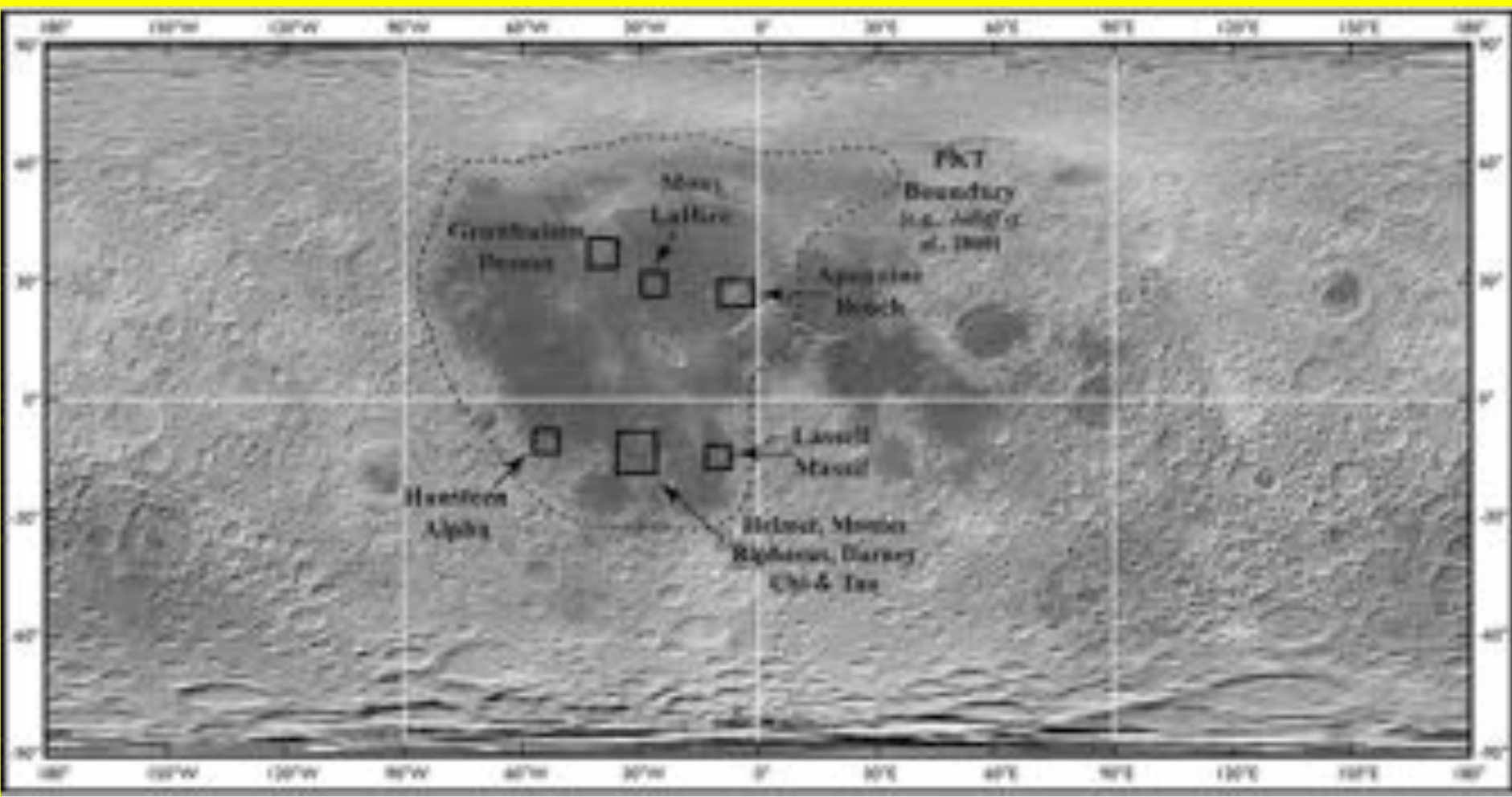
AGE, Ga



Lunar Crustal and Magmatic History

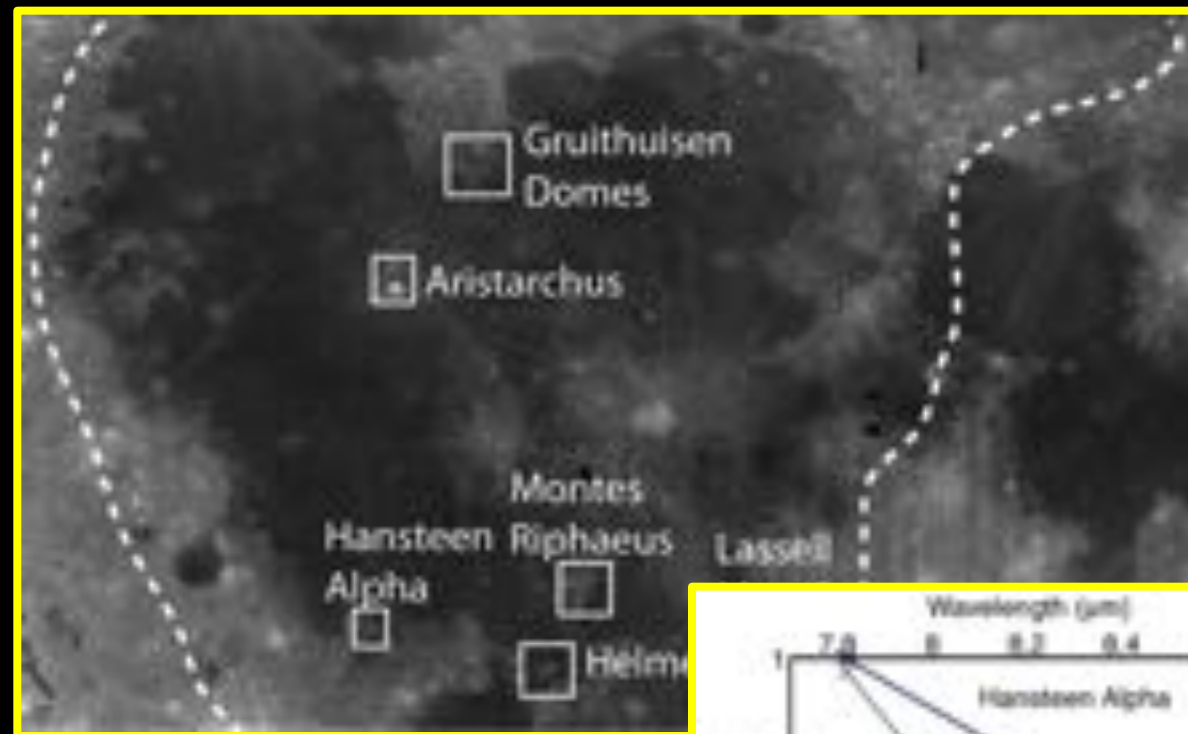


Global Distribution of Red Spots



(Hagerty et al., 2006) (Hagerty, 2014)

Enhanced Thorium Anomalies.



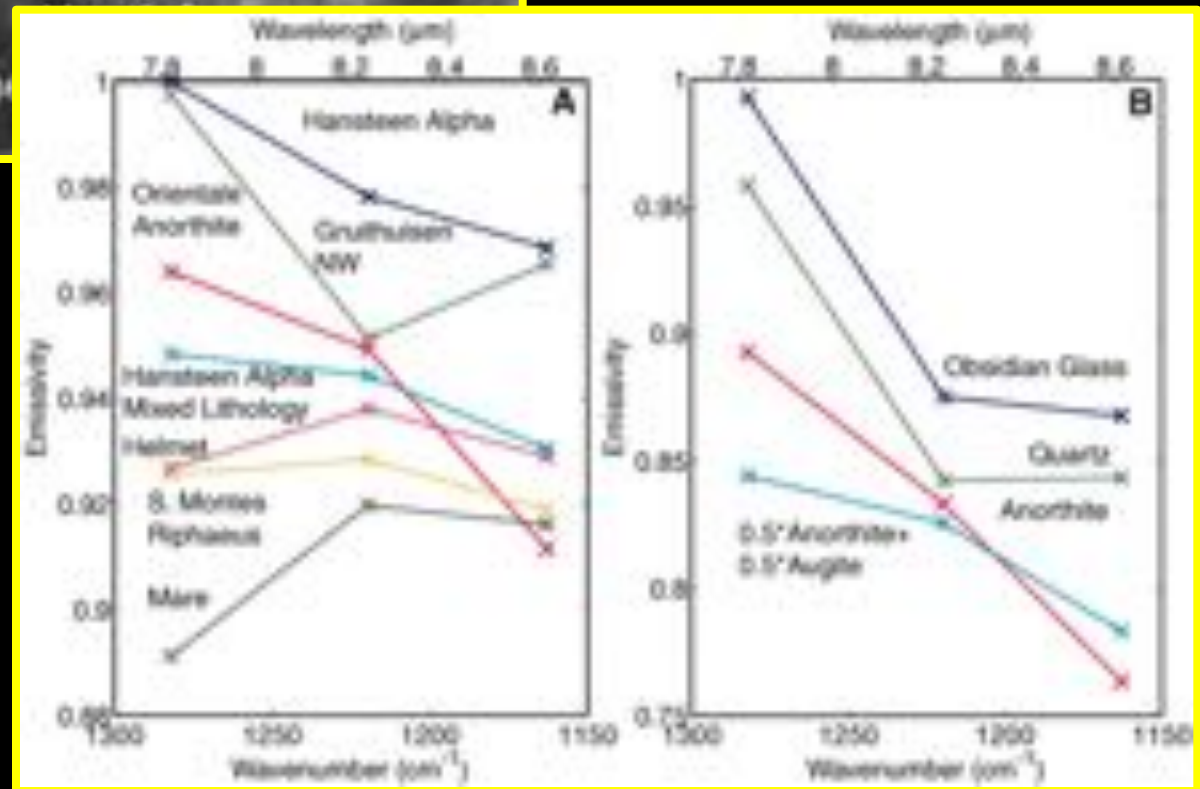
LRO DIVINER DATA

**Quartz,
Silica-Rich Glass
or
Alkali Feldspar.**

(Glotch et al., 2010)

Petrogenesis:

- 1) Silicate Liquid Immiscibility.
- 2) Basaltic Underplating,
- 3) Fractional crystallization.



Lunar Rock Types

Maria



Basalt



Basalt



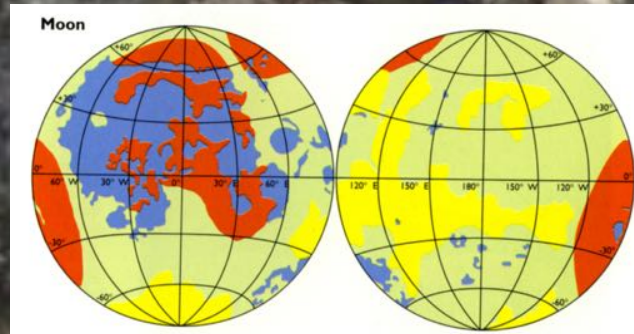
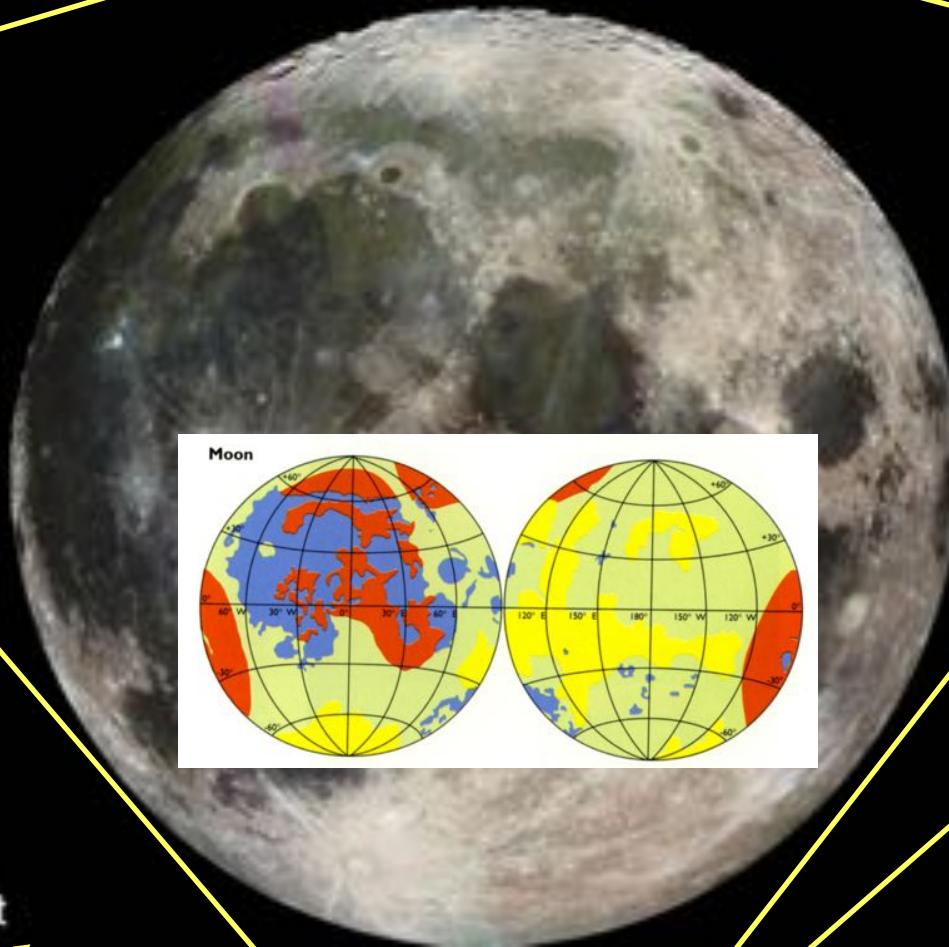
Anorthosite



Norite



Troctolite



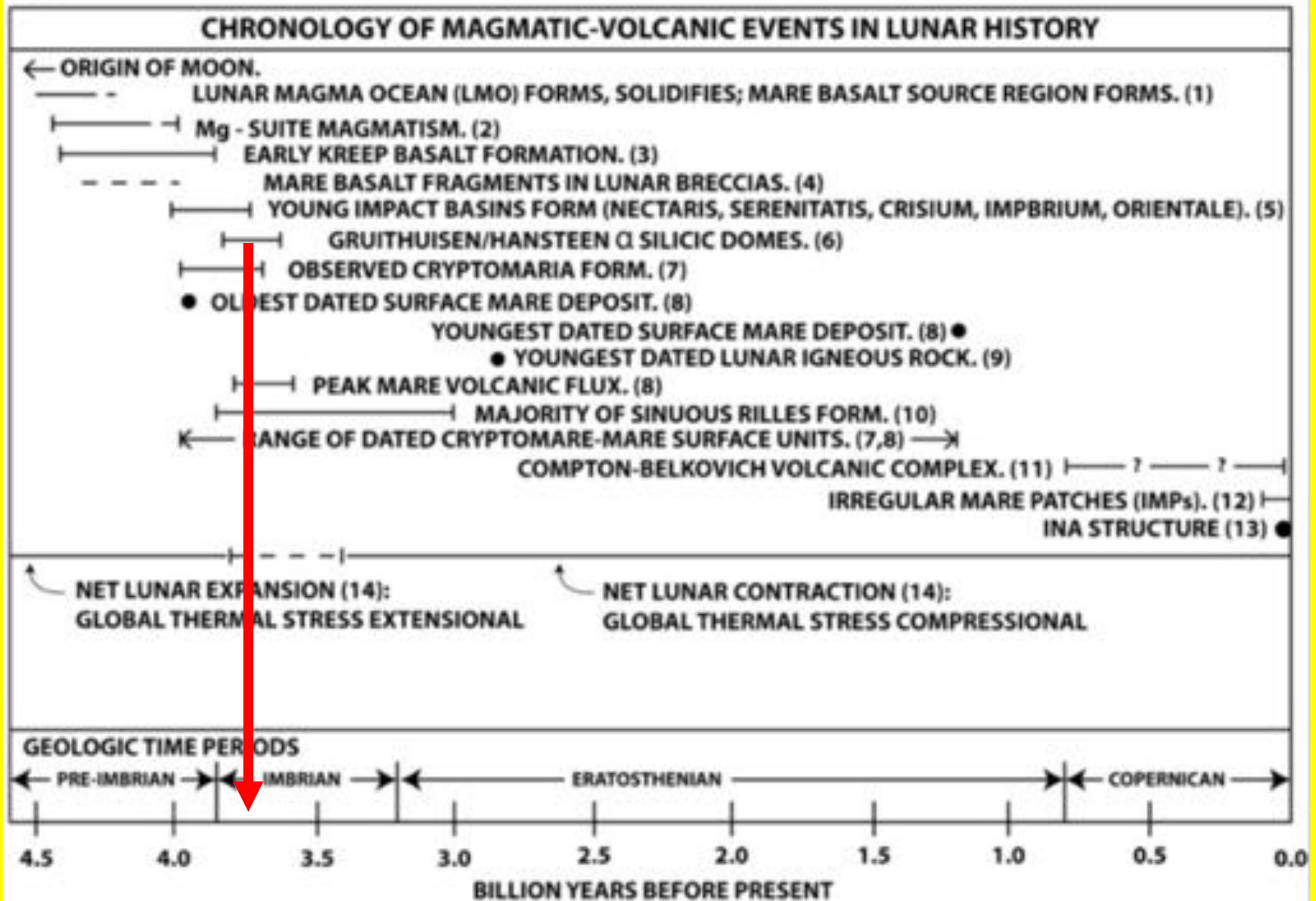
Breccia



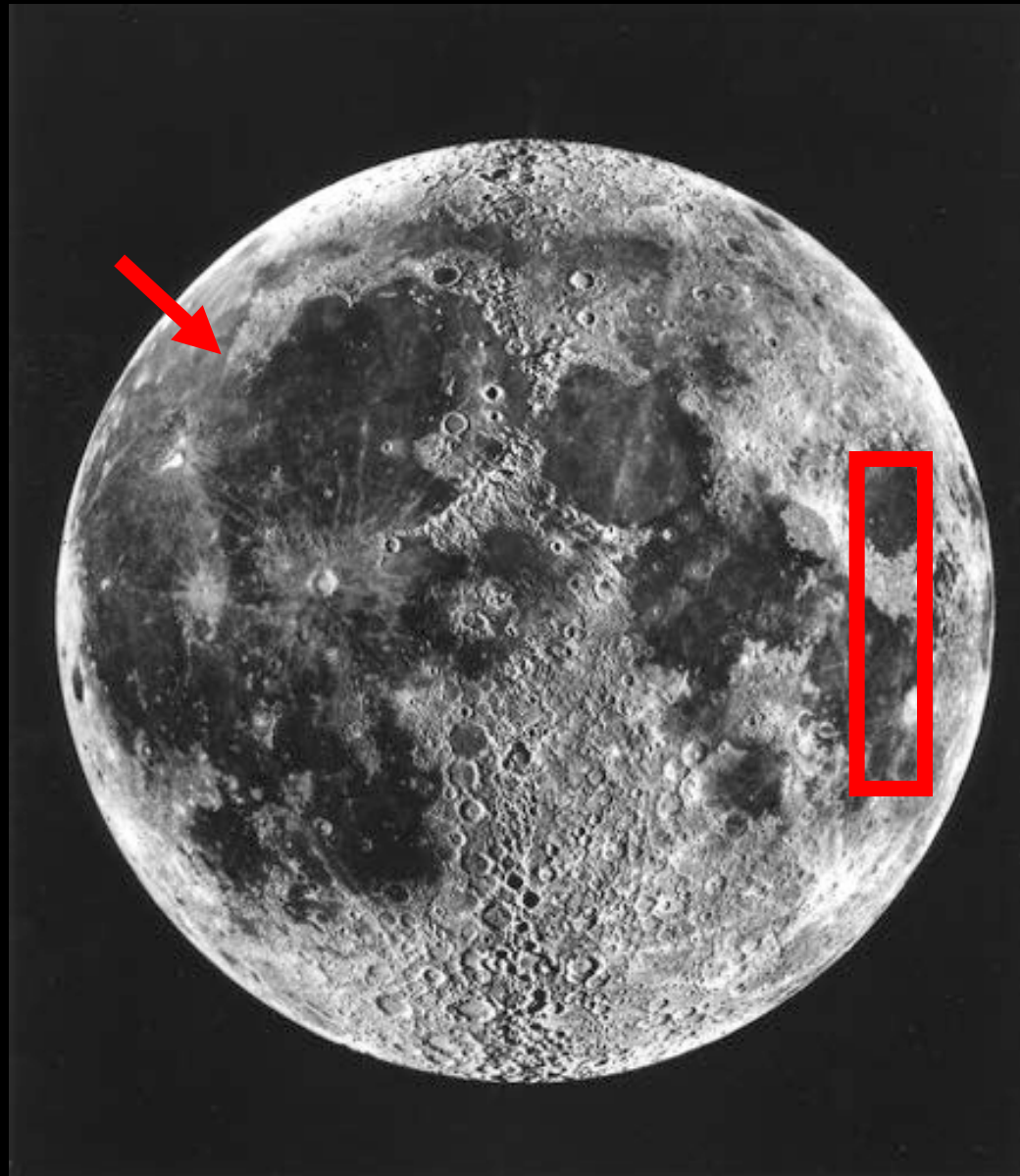
Impact melt

Highlands

Lunar Crustal and Magmatic History



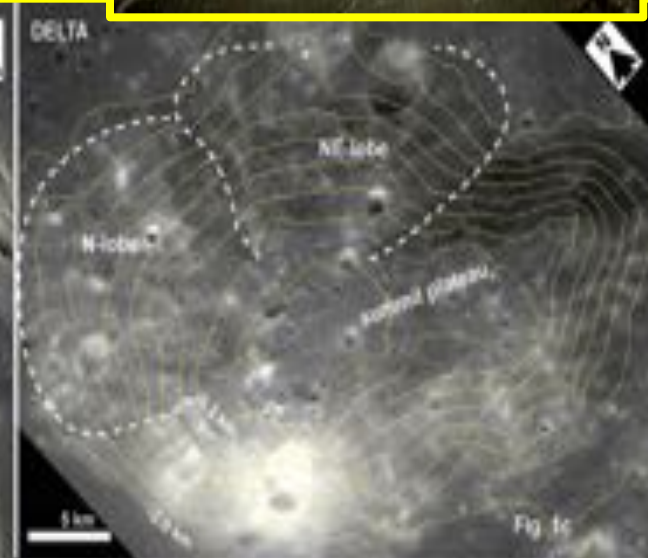
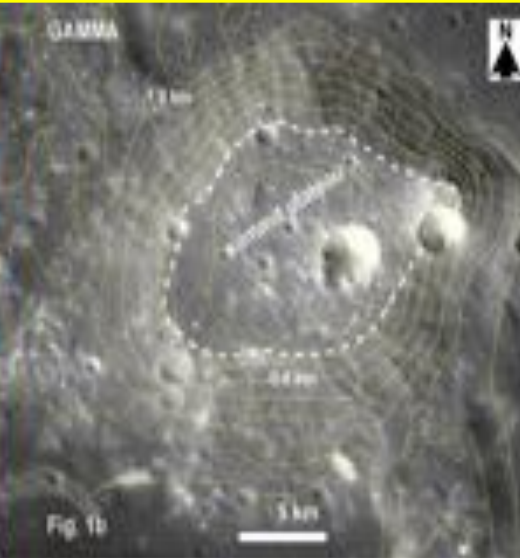
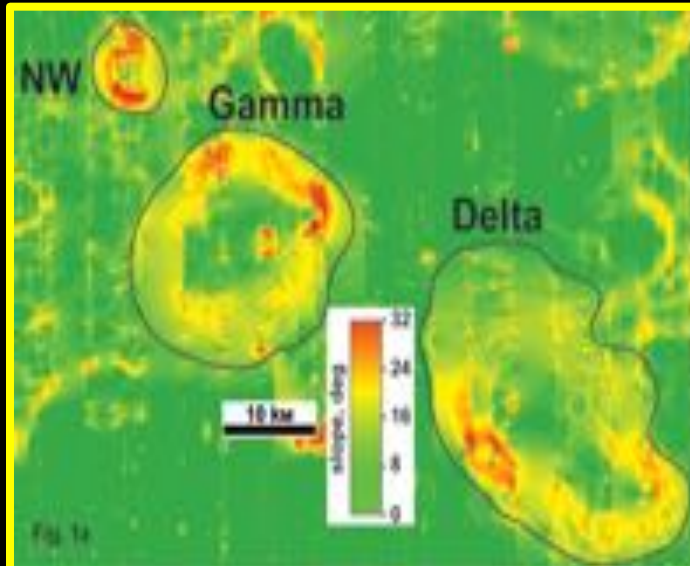
Early Attempts at **Red Spot** Sample Return



**Luna
Sample Return
Missions**

Lunar Science for Landed Missions Workshop

- Short-Term Reconnaissance/Surface Science Experiments:
- Long-Term Monitoring (days/years):
- Regional Roving Experiments:
- Sample Return:



Go Gruithuisen!!



